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Potentials and limitations of isotope analysis in Early Medieval archaeology

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In recent years there has been a great increase in the application of stable isotope analysis to Roman and medieval cemetery populations. However many methodological and conceptual issues have not yet been resolved. An understanding of the potentials and limitations of the method is central for using stable isotope analysis to its full advantage. Palaeodietary studies can increase in subtlety by comparing different tissue types (e.g. collagen and enamel apatite) and by using statistical methods, such as linear mixing models or Bayesian models, to trace the different components of a diet. In isotopic applications to migration, problems revolve around correctly identifying a local signal vis-à-vis the variability in the data. To maximise the potential of isotope studies isotopic data is ideally contextualised with other sources of data (e.g. osteology, archaeobotany, material culture). Finally, it is necessary to frame questions in such a way that the resulting interpretations go beyond the descriptive. This is of particular relevance to the issue of the 'Great Migrations' where isotope studies may yield new insights into mobility patterns and effects on identity.

Keywords: early medieval period, stable isotope analysis, palaeodiet, mobility, early medieval society

Negli ultimi anni le analisi degli isotopi stabili hanno visto una crescente applicazione sulle popolazioni dei cimiteri romani e medievali, e tuttavia molti problemi metodologici e concettuali rimangono ancora da risolvere. Una comprensione delle potenzialità e dei limiti di questo metodo è centrale per sfruttare appieno le analisi degli isotopi stabili. Gli studi sulla paleodieta possono migliorare utilizzando differenti tipi di tessuto (ade esempio collagene e apatite proveniente dallo smalto dentario) e usando metodi statistici, come il "mixing model" lineare oppure i modelli Bayesiani, per tracciare le differenti componenti della dieta. Per l'applicazione agli studi migrazionistici, i problemi riguardano la corretta identificazione dei luoghi di provenienza a partire dalla variabilità dei dati. Per massimizzare il potenziale delle analisi sarebbe ideale contestualizzare i dati con altre fonti (es. osteologia, archeobotanica, cultura materiale). È anche necessario porre le giuste domande di ricerca, per ottenere interpretazioni. Queste tematiche sono di particolare rilevanza per il "periodo delle Migrazioni", in cui gli isotopi possono dare una nuova chiave di lettura per gli schemi migratori e le identità.

Parole chiave*: altomedioevo, analisi di isotopi stabili, paleodieta, mobilità, società altomedievale*

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These old bones will tell your story
These old bones will never lie
These old bones will tell you surely
What you can't see with your eye
(Dolly Parton, Halos and Horns, 2002)

Over the past ten years, isotopic studies of early medieval populations have proliferated. Isotope analysis of past human populations falls into two broad research areas: studies of past diet and studies of mobility. Palaeodietary studies are frequently used to examine whether social structure such as gender or status differences is reflected in different diets. For mobility studies, isotope analysis is seen as a novel, and in some ways unbiased, tool – due to its scientific nature – for addressing questions regarding the historicity, extent and effect of the early medieval migrations. Differently from other forms of evidence, such as artefacts which could have moved through trade or gift-giving, isotope analysis can provide direct information about a person's mobility in the past. The method is therefore seen as a way of building evidence for past migrations from the ground up.

However, as isotopic studies become more and more part of the standard portfolio of cemetery analysis, there is a danger of succumbing to what Wolfram has termed "Vorspung durch Technik", i.e. the notion that objective scientific evidence can provide new interpretations of the past without the need for theoretical reflexion of the basis of these interpretations (Wolfram 2000). Isotopic analysis is indeed a powerful tool. Since it uses individuals as the primary unit of analysis it allows us to get very close the circumstances of peoples' lives in the past. However, an undirected accumulation of data or an unreflected application to existing preconceptions about past events does not do justice to its full potential.

This article will provide an overview over some of the methodological and conceptual issues that hold back applications of isotope analysis to early medieval questions.

1. Methodological complexities

Even though isotopic studies, in particular palaeodietary studies, have developed an established methodology since they were first applied to archaeological populations in the 1980s (Krueger, Sullivan 1984; Longinelli 1984; Schoeninger, DeNiro 1984; DeNiro 1985; Ambrose 1986; Schwarcz 1991; Schwarcz, Schoeninger 1991) new complexities and limitations are constantly identified. While these make the method more robust in the long run, this also means that the conclusions of many earlier studies may have to be reassessed. The background and principles of isotope analysis are comprehensively discussed by Vohberger (this volume). In the following, I will draw attention to some methodological issues which may be of particular relevance to European medieval populations.

1.1. Sample material

Collagen is the main component of connective tissue. It forms the structure around which bone subsequently mineralises. Collagen is a protein, and the amino acids needed for its formation are preferentially routed from the protein in diet. The turnover rate, the rate at which bone is remodelled, is crucial for comparing samples from within a population.

Isotopic results from collagen are frequently assumed to relate to a period approximately ten years before death. However, a study by Hedges *et alii* (2007) of collagen turnover in modern human femurs showed that isotope values represent diet over a much longer period than ten years and include a substantial proportion of diet ingested during adolescence. They state that 'even at age 50 years there is a 40% representation of collagen synthesised at age less than 25 years' (Hedges *et alii* 2007, p. 815). The turnover rate is likely to be higher in rib bone since it contains a higher ratio of trabecular to cortical bone, compared to a femur. Skull bones on the other hand have the lowest turnover rate of all parts of the skeleton. Dentine, the collagen component of the roots of teeth, is not remodelled once teeth are fully formed during childhood and adolescence (Nanci 2003). Isotopic signatures from dentine therefore provide information specifically about the time period during which the tooth roots were formed. Samples from different parts of the skeleton thus open up time windows into different periods in an individual's life (e.g. Schroeder *et alii* 2009). For dentine the date ranges are clearly constrained, whereas for bone the isotopic signature represents an average that is skewed towards the end of life. This will affect the interpretations of the data.

Bone and dentine are rich in organic material (>20%) and poorly crystalline, while tooth enamel is nearly anorganic (<2%) and highly crystalline with fewer defects and substitutions (LeGeros 1981). The mineral component of bones and teeth is apatite, a phosphate mineral (e.g. $Ca_{10}(PO_4)_6(OH)_2$) which allows various substitutions to take place within its crystal lattice (e.g. Sr^{2+} for Ca^{2+} or carbonate (CO_3^{2-}) for phosphate (PO_4))(LeGeros *et alii* 1969). Due to its weak crystal structure, bone apatite is subject to diagenetic alterations in the burial environment since the same processes that cause ion substitutions in life may continue after death. Thus bone apatite has been shown to take on strontium isotope ratios of the burial environment to such a degree that it is used as a marker for the local isotopic signature (Brettell *et alii* 2012a). Since the crystal structure of enamel apatite is of better quality than that of bone, it is resistant to such alterations. Attempts have been made to distinguish diagenetic alterations of bone apatite from its *pre mortem* isotope ratios (Shin, Hedges 2012). However, as yet these are experimental and have not yet been widely tested. This means that tooth enamel is a useful tissue for isotopic analysis, whereas studies involving bone apatite have to be viewed with extreme caution.

1.2. Palaeodietary studies

Palaeodietary studies investigate carbon and nitrogen isotope ratios, generally in bone collagen. Nitrogen isotope ratios are plotted against carbon isotope ratios to determine proportions of animal protein and of C3 or C4 plants in the diet (Lee-Thorpe 2008). In recent years a number of studies have reassessed earlier assumptions and have developed approaches that provide more detail to the broad-brush picture provided by simple bi-plots.

Since isotope ratios in collagen are primarily derived from protein, the contribution of animal protein to diet is easily overestimated. Enrichment of nitrogen isotopes with each trophic level is generally considered to be +3-4‰. However, individual studies indicate that there can be variation between +1.5 and 6 ‰, depending on species and specific ecosystem (Caut *et alii* 2009). O'Connell *at alii* (2012) suggest that for humans the diet-collagen offset is c. 6‰ which would mean that animal protein intake has been overestimated in many studies of prehistoric and historic populations.

Soil manuring can also raise the nitrogen isotope ratios in both plants and their consumers (animal or human). Human populations eating grain grown on heavily manured soils may therefore appear to have consumed more animal protein than was actually the case (Bogaard *et alii* 2007). This effect can by controlled by 'calibrating' human isotope values with those of animals that likely consumed plants from the same soil (Czermak *et alii* 2006; Strott *et alii* 2008; Lightfoot *et alii* 2012).

Grupe (this volume) draws attention to the limitations of simply plotting carbon against nitrogen isotope ratios since this frequently overestimates the contributions of animal protein to the diet. Linear mixing models developed by Phillips *et alii* (Phillips, Gregg 2001; Phillips, Koch 2002; Phillips, Gregg 2003; Phillips *et alii* 2005) allow us to determine the proportion of three dietary components when isotopic data from two elements is available. Bayesian statistical models developed in ecology such as SIAR and SIBER take this further (Parnell *et alii* 2010; Jackson *et alii* 2011).

Carbon isotope ratios can provide further information about diet. Differently from collagen, apatite is formed from contributions from the whole diet (Kellner, Schoeninger 2007). When compared to carbon values from collagen or dentine, differences in the isotopic signatures of different dietary components can be teased apart (e.g. a diet that is made up of marine protein and C3 plants will plot differently to a diet that is made up of C3-fed animal protein and C4 plants) (Kellner, Schoeninger 2007). This enables us to identify smaller contributions of C4 plants to the diet. This is of particular relevance for pre-modern Europe where millet, the only known cultivated C4 plant, provided a much smaller contribution to diet than maize in the Americas. If different teeth are compared, such an approach also allows us to investigate shorter-term dietary changes during childhood.

1.3. Migration and mobility

The isotope ratios of strontium and oxygen in enamel apatite can reveal information about local or non-local origins of an individual, relative to his or her place of burial (Bentley 2006). This requires, first, a securely determined local signature. For strontium this is most usefully done by taking a range of samples from local water, vegetation, fauna and burial soil, as well as by analysing human bone apatite which may be diagenetically altered so as to have become similar to the burial environment (e.g. Knipper 2012). Vohberger (2011, pp. 142-169) has drawn attention to the difficulties of doing this in areas that are geologically variable, since we have to assume that even an entirely non-mobile population would have used food resources from within a certain radius. Unfortunately the location of the settlement associated with early medieval cemeteries is frequently not known, making the appropriate local signature even more speculative.

This is even more problematic in the case of oxygen. As described in Vohberger (this volume), oxygen isotope ratios in meteoric water vary depending on latitude and altitude. Oxygen isotope ratios in human enamel are derived from drinking water. To be able to determine locality or non-locality in a cemetery population, the measured $\delta^{18}O$ values from enamel phosphate have to be converted to predicted $\delta^{8}O$ values in drinking water. These values can be compared with maps of oxygen isotope ratios in modern meteoric water (e.g. IAEA/WMO 2006) to identify potential migrants within a population.

A number of linear regressions have been developed to convert values from enamel to drinking water (Longinelli 1984; Luz *et alii* 1984; Levinson *et alii* 1987; Daux *et alii* 2008). Pollard *et alii* (2011) noted substantial error ranges in the predicted outcome for all four equations, as well as for their own 'super calibration' (ranging from ±1-2 ‰ for Longinelli (1984) to ±3.5 ‰ for Levinson et al. (1987) with 95% confidence). Predictions of $\delta^{18}O$ values in drinking water from human enamel values are therefore not very precise.

A further problem lies in the great variability of oxygen data from European cemetery populations. The $\delta^{18}O$ phosphate value ranges of different sites are 4‰ on average. Sites in Britain have a narrower range (e.g. Roman Gloucester and Catterick, both 2.1‰; Chenery *et alii* 2010; Chenery *et alii* 2011), while others, for example in Rome, may have a wider distribution (e.g. Isola Sacra, 6.4‰; Prowse *et alii* 2005). This is greater than the differences in drinking water oxygen isotope values across Europe from north to south. For example the average values for $\delta^{18}O$ meteoric water in Britain lie between -5 and -8.5‰, while for Rome the range is -3.6 to -6.5‰ (IAEA/WMO 2006). This is a difference of around 4-5‰ between Britain and Italy, less than the intra-site variation of Isola Sacra. Some of this variability may be explained with the presence of migrants. However, while isotope values of meteoric water provide consistent patterns over the large-scale and long-term, they can vary significantly over the short term and in different local water sources (e.g. depending on their altitude). Other sources of liquid also have considerable variation in their oxygen isotopes. Milk, wine and juice are enriched in ^{18}O relative to local water (Förstel, Hützen 1983; Bong *et alii* 2008; Chesson *et alii* 2010), and Brettell *et alii* (2012b) have shown that $\delta^{18}O$ values can be increased by up to 4.4‰ relative to water when liquids are boiled, brewed or stewed. The consumption of liquids other than unmodified water can therefore make the $\delta^{18}O$ values of enamel phosphate more positive. At present it seems that oxygen data are too variable to allow us to answer questions about long-distance migration. They have however been used successfully to investigate high altitude residence (e.g. in Volders, Austria; McGlynn 2007), possibly because oxygen isotope variations in Alpine water are greater than variation caused by cooking and fermenting.

1.4. Statistical methods

All isotopic studies require adequately large sample sizes so that robust statistical interpretations can be made. Smaller sample populations may appear artificially normally distributed and data variability is amplified.

This may be particularly problematic if the data are investigated according to a range of social variables (e.g. sex, age, grave type and status). Mass spectrometers have measurement errors, e.g. less than ±0.2‰ for $\delta^{13}C$ and $\delta^{15}N$. If the mean differences between each data sub-category are near the measurement error this may create statistically significant results which could be quite different if the sample population was larger.

Standard statistical methods are not designed to deal well with outliers. Yet, in archaeological studies these outliers may be of particular interest, for example by identifying individuals as migrants. Frequently 'outliers' are defined as lying outside of two standard deviations from the mean. This makes an assumption that 5% of a population migrants. This may be a statistically practical assumption, but it is archaeologically questionable. Further, not all isotopic data are normally distributed (e.g. Altenerding; Hakenbeck *et alii* 2010).

As a final *caveat* regarding isotopic studies of migration, we need to consider the possibility that migrants may remain undetected because the 'local' and the 'non-local' signature are isotopically indistinguishable.

1.5. Integration with other methods

Stable isotope studies yield the most interesting results if the full range of isotopes is combined (carbon, nitrogen, strontium, oxygen and also sulphur) and if a number of different tissue types are analysed (e.g. Schroeder *et alii* 2009). A greater number of variables adds complexity and subtlety and is a safe-guard against simplistic interpretations. A number of studies have also shown that isotope analysis yields the best results in combination with other methods such as zooarchaeology, archaeobotany or physical anthropology (e.g. Inskip, this volume; Killgrove, this volume; Bocherens *et alii* 2006).

2. Conceptual complexities

As isotope analysis has become cheaper and more accessible, the number of studies that employ the method without a rigorous conceptual or theoretical framework has unfortunately also increased. Thus many studies of palaeodiet limit themselves to asking 'What did they eat?' while studies of migration are often reduced to 'Are there foreigners in this cemetery population? Did they come from…?' The conclusions of such studies can be very descriptive and, even worse, they may uncritically employ simplistic notions of past people's behaviours.

2.1. Diet and society

Information about diet can provide a rich resource for investigating broader questions about past societies. These can relate to wider economic issues, as well as to status, gender, religion and also mobility. This is exemplified by a number of isotopic studies of British cemeteries from the Iron Age through to the Anglo-Saxon period which enable us to trace fluctuating uses of diet as a form of social distinction. In the multi-period cemetery at Poundbury, Richards *et alii* (1998) identified a dietary shift from the late Iron Age through to the Roman period. Individuals from the Iron Age and early Roman period consumed a homogeneous diet that was based mostly on plants and terrestrial animals, a pattern that follows on from the middle Iron Age (Jay, Richards 2006). Status distinctions appear in the late Roman period when some individuals are buried in mausolea and others in wooden coffins. The food of the higher-status individuals in mausolea was more homogeneous and appeared to have included greater proportions of marine resources. A study of 22 Anglo-Saxon cemeteries from southern and eastern England has shown that diet was extremely variable (Hull, O'Connell 2012). This was evident in particular in human nitrogen isotope values which ranged from 6‰ to 14‰. This can partly be explained by local isotopic differences that are reflected in the associated fauna. Thus in different sites the $\delta^{15}N$ values of the same species could vary by up to 4‰ and $\delta^{13}C$ by up to 2.5‰. However, analysis of the data according to gender and burial wealth also showed differences between sites. This is consistent with the great variability that is characteristic of Anglo-Saxon burial practice (Lucy 2000; 2002). Compared with earlier Roman diet, Anglo-Saxon diet is lower in $\delta^{13}C$, suggesting that a greater range of food was available during Roman times. From the middle Saxon period onwards marine resources seem to have been increasingly incorporated into the diet, perhaps initially linked to the emergence of monastic communities (Hull, O'Connell 2012).

From the late seventh century AD onwards we can see increasing social stratification in many parts of central and northern Europe (Stein 1967; Geake 1997; Burzler 2000). Isotopic studies of fifth- and sixth-century populations in southern and central Germany identified no dietary distinction according to status (Hakenbeck *et alii* 2010; Knipper *et alii* 2013). However, by the eighth century AD this changed considerably. An isotopic and osteological examination of several small high status cemeteries in Bavaria showed that individuals in high status burials were privileged in terms of their health and nutrition (Czermak *et alii* 2006; Strott *et alii* 2008; Czermak 2011). They had lower incidences of degenerative joint disease, suggesting a less strenuous lifestyle, and, in some cemeteries, greater access to animal protein. Isotopic evidence also suggests that elite was more mobile. We can see here the emergence of a nobility that distinguished itself from the lower ranking population through access to different foods, different activities, greater mobility and separate burial grounds.

None of these studies note any consistent dietary differences between men and women. These become apparent only in later periods. An investigation of dietary change in Orkney from the Pictish period (fourth-ninth centuries AD) to the later medieval period (eleventh-sixteenth centuries AD) showed a significant increase in marine dietary resources in the Viking period (ninth-eleventh centuries AD), particularly among men (Barrett, Richards 2004; Richards *et alii* 2006). Fishing apparently only became an important economic strategy at this time. At the same time the consumption of marine resources developed as a gendered practice, possibly related to divisions of labour. The authors put these results in the context of economic changes in medieval England that lead to an expansion of fishing by the end of the first millennium.

These studies highlight the value of putting isotopic results in a wider context, both by examining them alongside other bioarchaeological evidence and by interpreting them with a bigger picture in mind.

2.2. Analysing migrations

Isotope analysis is assumed to have great potential in investigations of the early medieval migrations. It is seen as an independent method to verify the narrative of the migrations of the barbarian tribes such as the Anglo-Saxons, Lombards or Visigoths provided by the historian and ethnographers of late Antiquity. The historicity of these accounts continues to be hotly debated by historians and archaeologists alike[1]. Questions revolve around who migrated, in what numbers and what the effects of these migrations might have been. Traditional archaeological approaches have tried to trace the movement of people through the movement of artefacts, particularly those that were assumed to be part of ethnic dress and therefore less likely to have been traded. However, such an approach has been criticised as employing simplistic notions of

[1] Complex contrasting historical perspectives are provided by Pohl (recently Pohl 2005) and Goffart (e.g. Goffart 1989; Goffart 2006) and their colleagues. In archaeology, matters are more polarised. A fault-line runs between scholars who read late antique narratives of migrations as historical facts (frequently much less critically than historians) that can be traced archaeologically (e.g. Bierbrauer 2008) and the opposing view that emphasises culture change over large scale migrations (see articles in Brather 2008).

ethnicity and the role of dress in the early medieval period (von Rummel 2007; Hakenbeck 2011). Isotope analysis therefore seems a way out. It is perceived as a way of obtaining objective data regarding the extent of population mobility and the geographical origins of people who moved[2].

Studies that take an established migration narrative as a starting point – whether to prove or disprove it – necessarily have to limit themselves in their search for possible explanations of a pattern in the data. Thus Evans *et alii* suggest that 'foreigners' in a fourth-century cemetery in southern England may have been Sarmatians from Pannonia, Schweissing and Grupe postulate migration to Bavaria from Bohemia in the fifth century AD, Brettell *et alii* look to the North Sea littoral for the origins of the Anglo-Saxons and Prevedorou *et alii* aim to determine north African origin for an eighth-century individual from Pamplona, Spain (Schweissing, Grupe 2003; Evans *et alii* 2006; Prevedorou *et alii* 2010; Brettell *et alii* 2012a). Testing a hypothesis based on a historical framework is a scientifically sound approach. However, the resulting conclusions are limited to either refuting or affirming the original hypothesis. Pre-determined ideas about early medieval migrations may be challenged in this way (e.g. Knipper 2012), but such an approach does not put forward new ideas about the nature of mobility.

Yet, some studies are beginning to show that mobility can be a more complex and varied phenomenon than simply the migration of large populations. Using multiple evidence classes – osteology, isotopic evidence, as well as contextual archaeological evidence and historical sources – Killgrove (2010, and this volume) investigated the lifestyle and health status of migrants to Imperial Rome. She was able to identify significant immigrant numbers amongst lower-class populations, some of them from outside of the Italian peninsula. This included people of both sexes and children. The quality of life of these immigrants seemed to have been similar to the rest of the urban poor.

A project examining the ethnic diversity of populations in Roman Britain combined isotope analysis, osteology (including craniometric ancestry determination) and the associated archaeological evidence (e.g. Chenery *et alii* 2010; Leach *et alii* 2010; Chenery *et alii* 2011; Müldner *et alii* 2011). Amongst many others, the authors examined the case of a woman in Roman York who was buried with high status grave goods such as

[2] In an interview with Alexander Gramsch (2010, pp. 210), Friedrich Lüth, in charge of cultural heritage and site management at the German Archaeological Institute, suggests of his new project on tracing Langobard migrations that it is not necessary to 'put the topic 'migration' on the theoretical agenda again, rather […] to understand first whether it is possible to gain new proxy data from the existing sources [i.e. isotopic data], which then can be made accessible for the research into migrations. This then would be the second step, not the other way round.'

bracelets made from elephant ivory and local jet, earrings and a glass jug, as well as an openwork bone mount with Christian associations. Craniometrically this woman appears to have been partly of African and partly of European descent, suggestive of north African origin. Isotopic evidence (Sr and O) from her tooth enamel suggests a childhood in the west of Britain or coastal areas of western Europe or north Africa. The example of this woman highlights the complex relationship between mobility and identity. It contradicts common assumptions that only men associated with the military were mobile across long distances in the Roman period. It also shows that a woman who may have looked quite different from the indigenous Romano-British population was accorded a high-status burial.

Using diet to investigate migration, Hakenbeck *et alii* (2009; 2010) arrived at similar conclusions in a study of gender-specific mobility in fifth- and sixth-century central Europe. An examination of the distribution of individuals with modified skulls, a practice that has been associated with the Huns, showed that individual adult women were mobile over long distances, suggesting exogamous marriage practices. Isotopic analysis of cemeteries in late Roman and early medieval Bavaria investigated the proportion of individuals that did not grow up locally, the potential direction of their movements, and how migration processes influenced the identities expressed in burial practice. Results showed that some individuals with skull modification did indeed have non-local dietary signatures while others did not. Interestingly grave goods and burial practice were entirely local and provided no evidence of mobility. Following the migration, a profound shift in identity appears to have taken place since individuals with skull modification who must have clearly looked 'foreign' were buried in the local manner. This study showed that the relationship between mobility, appearance and ethnic identity was not straightforward. A 'mismatch' between local or foreign grave goods and isotopic results has also been noted elsewhere (Evans *et alii* 2006; Knipper 2012). This is clear proof – if further proof were needed – that artefacts and burial practice alone are a poor indicator of people's mobility.

A further example is provided by Inskip (this volume). She investigates mobility in the context of conversion to Islam in early medieval Iberia. While there are far-reaching changes in body morphology between pre-Islamic and Islamic populations, isotopic evidence does not support large-scale migration from north Africa during this time. Instead the evident changes appear to have been due to changes in practice following religious conversion. Inskip's work overturns the established historical model of an Arab invasion into Iberia and emphasises instead indigenous responses to a new religion.

It is important to remember that isotope analysis can only reveal first-generation immigrants, so the long-term effects of migration on a society can only be examined through other strands of evidence, such as osteology (e.g. craniometric ancestry determination) and aDNA. Material culture and burial practice of course also provide important insights. In the cemetery of Altenerding, Bavaria, kinship identity was expressed through use of brooches of 'foreign' styles (Hakenbeck 2011, pp. 116-117). 'Family burial areas' were evident over several generations and created links to a real or imagined place of origin through the use of material culture.

3. Conclusion

Isotope analysis provides us with a data set that is almost unique in archaeology: information about specific individuals at different points in their lives. Sampling of multiple tissue types and analysis of multiple isotopes can reveal a fascinating and highly detailed picture of a person's life. However, such detail also constitutes a problem. A small and highly individual sample set does not provide a solid foundation for inferences of a more general nature, especially considering the long timeframes and geographical scales that we are dealing with in archaeology. There is a danger of giving the existing data a greater explanatory power than they might actually have. This problem can be alleviated by using very large sample sets and by increasing the number of isotope studies from different time periods and different regions. An accumulation of more data will lead to more and more solid interpretations of societal trends.

Luckily we do not have to reply on isotopic data alone. A truly interdisciplinary approach enables us to contextualise highly specific data: attendant osteological information about sex, age, health and activity markers, as well as – potentially – ancestry determination, can build up a rich picture of an individual's circumstances of life and death. This can be further combined with archaeological information about the nature of the burial, the cemetery and its broader context, as well as information from historical sources.

The archaeology of the early medieval period operates within much smaller timescales than prehistoric archaeology and is rich in contextual information. This makes it a particularly good candidate for taking full advantage of the possibilities provided by stable isotope analysis and gives us the opportunity to build interpretations about past societies from the ground up.

In doing so, it is useful to consider the different scales of our inferences, both in a temporal and in a geographical sense. To understand the role that individuals played within and how their lives were shaped by the social changes that took place during late Antiquity and the early medieval period is one of the big challenges of the archaeology of the period. However, how much new insight isotope studies will provide depends not only on being aware on the methodological potentials and limitations of the method but also on engaging with the theoretical potential provided by the method and the nature of the questions that are being put to it.

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